DEVELOPMENT OF m THEORY PART TWO: THE ORBIT OF S2, LIGHT DEFLECTION DUE TO GRAVITATION AND VELOCITY CURVE OF A WHIRLPOOL GALAXY.

by

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ABSTRACT

The m theory of physics and astronomy is applied to the orbit of the S2 star to show that its precession is a hundred times smaller than that predicted by Einsteinian general relativity. The m theory is used to describe the velocity curve of a whirlpool galaxy, where the Einstein and Newton theories fail completely. It is shown that m theory gives a precise description of the deflection of electromagnetic radiation by gravitation, and a precise description of the gravitational red shift .

Keywords: ECE2 unified field theory, m theory, the orbit of S2, light deflection due to gravitation, the velocity curve of a whirlpool galaxy.

4FT 419

1. INTRODUCTION

In recent papers of this series {1 - 41} a generally covariant unified field theory of physics and astronomy has been developed in the most general spherical spacetime, and given the appellation "m theory". The m theory has been shown in immediately preceding papers to be rigorously self consistent and to rigorously obey conservation laws. It is capable of giving forward and retrograde precessions of orbits, shrinking and expanding orbits, superluminal propagation, and infinite potential energy from m space (synonymous with "spacetime" or the vacuum"). In Section 2 of this paper m theory is applied to the orbit of the S2 star, the deflection of electromagnetic radiation by gravitation and the velocity curve of a whirlpool galaxy. It is shown that Einsteinian general relativity (EGR) fails by a factor of about a hundred to describe the observed precession of the S2 star, while m theory gives a precise description. Similarly, the Newton and Einstein theories fail completely to describe the velocity curve of a whirlpool galaxy whereas m theory succeeds. Finally it is shown that m theory gives a precise description of the deflection of electromagnetic radiation by gravitation in a far simpler manner than EGR. The latte predicts a forward precession of 0.218 degrees per orbit of S2, but this precession is not observed.

This paper is a brief synopsis of extensive calculations in notes accompanying UFT419 on www.aias.us. In note 419(1) it is shown that the S2 orbit is very close to being Newtonian, a static ellipse with a very small precession. The small difference is accounted for with a static m function that gives a forward precession of 0.0033 degrees per orbit. This finding completely refutes EGR, which gives a forward precession of 0.218 degrees per S2 orbit. In Note 419(2) the m theory is applied to light deflection due to gravitation, accounting for the experimental result in a manner that is far simpler than EGR, and preferred by Ockham's Razor. Any small deviations that many be found by precision astronomy are accounted for by an m function. Note 419(3) describes self inconsistencies in the standard model analysis of S2. Note 419(4) develops the three Kepler laws in m theory, and Note 419(5) develops the m theory of the velocity curve of whirlpool galaxies, showing that different galactic structures can be explained by different m functions.

2. APPLICATION OF M THEORY

The orbit of the S2 star around a large central mass has been studied for a number of years by several laboratories. On 18th May 2018 it went through a closest approach with the following parameters given by a wikipedia article on the net:

$$r = 1.7952 \times 10^{13} \, m$$
$$v = 7.650 \times 10^{6} \, m s^{-1}$$
$$a = 1.451 \times 10^{14} \, m$$
$$M = 8.572 \times 10^{36} \, kgm$$
$$G = 6.67408 \times 10^{-11} \, m^3 s^{-2} kgm^{-1}$$
$$\epsilon = 0.88466$$
$$T = 16.0518 \text{ earth years.}$$

Here r is the distance of closest approach, $\underline{v}$ is the orbital velocity at closest approach, a is the semi major axis of the S2 orbit, M the estimated central mass, ϵ the eccentricity, T the time taken for one S2 orbit, and G the gravitational constant. The S2 orbit from many observations over a quarter century is often assumed in the astronomy literature to be an ellipse, so it is Newtonian or Keplerian. If so the Newtonian orbital velocity must be:

$$v^2 = MG\left(\frac{2}{r} - \frac{1}{a}\right). \quad -(1)$$

However, the above wikipedia data give:

$$v^2 = 5.852 \times 10^{13} \, m^2 s^{-2} \quad -(2)$$

$$\underline{M}G\left(\frac{2}{r} - \frac{1}{a}\right) = 5.977 \times 10^{13} \; m^2 s^{-2} \quad -(3)$$

so there is quite a large discrepancy. The latter can be accounted for by m theory with constant m (r), in which:

$$v^2 = m(r)^{3/2}\underline{M}G\left(\frac{2m(r)^{1/2}}{r} - \frac{1}{a}\right). \quad -(4)$$

As described in Section 3 the S2 orbit is best described by m theory if the precession per S2 orbit is:

$$\Delta\phi = +0.0033^\circ. \quad -(5)$$

In so doing the Wikipedia data were found to be self inconsistent and must be modified. On the other hand, EGR gives the well known forward precession:

$$\Delta\phi(EGR) = \frac{6\pi \underline{M}G}{a(1-\epsilon^2)c^2} \quad -(6)$$

which for the above data is 0.218° degrees per orbit. This is about a hundred times too large, so EGR is completely refuted by the S2 orbit.

The central mass about which S2 orbits is derived by a routine Newtonian analysis:

$$\underline{M} = \frac{v^2}{G\left(\frac{2}{r} - \frac{1}{a}\right)} \quad -(7)$$

using known v, r, and a. There is nothing in this analysis to imply a "supermassive black hole", it is a classical Newtonian analysis that gives a large mass. Black hole theory is based on the Einstein field equation, which is well known to be erroneous due to lack of torsion, and which has been refuted in nearly a hundred different ways in the UFT series of www.aias.us.

The orbit of EGR is calculated from the infinitesimal line element in plane polar coordinates of the most general spherically symmetric spacetime {1 - 41}

$$ds^2 = c^2 d\tau^2 = m(r)\, c^2 dt^2 - \frac{dr^2}{m(r)} - r^2 d\phi^2 \quad -(8)$$

where m is a function of r , τ is the proper time, and (r , ϕ) is the plane polar coordinate system. The Einstein field equation constrains m (r) to one function:

$$m(r) = 1 - \frac{r_0}{r} \quad - (9)$$

where:

$$r_0 = \frac{2MG}{c^2} \quad - (10)$$

is the so called "Schwarzschild" radius. From Eq. (8) the orbit of EGR is:

$$\frac{dr}{d\phi} = r^2 \left(\frac{1}{b^2} - m(r) \left(\frac{1}{a^2} + \frac{1}{r^2} \right) \right)^{1/2} \quad - (11)$$

where a and b are constants.

Eq. (11) fails completely in S2 and also for whirlpool galaxies, in which both Einstein and Newton predict a zero velocity at infinite r. The observed galactic velocity reaches a plateau at infinite r. There is no way in which EGR can be regarded as a precise theory because it fails completely given the S2 and galactic data.

The orbit of S2 in m theory is given by simultaneous solution of:

$$\frac{dH}{dt} = 0 \quad - (12)$$

and

$$\frac{dL}{dt} = 0 \quad - (13)$$

given the initial conditions. Here:

$$H = m(r)\gamma m c^2 - m(r)^{1/2}\frac{mMG}{r} \quad -(14)$$

is the hamiltonian of m theory, and

$$L = \frac{\gamma m r^2 \dot{\phi}}{m(r)} \quad -(15)$$

its angular momentum. Both are constants of motion described by Eqs. (12) and (13).

The generalized Lorentz factor of m theory is:

$$\gamma = \left(m(r) - \frac{\dot{r}^2 + r^2\dot{\phi}^2}{m(r)c^2}\right)^{-1/2}. \quad -(16)$$

Therefore m theory uses a potential energy:

$$U = -m(r)^{1/2}\frac{mMG}{r} \quad -(17)$$

while Eq. (11) of EGR does not use the concept of potential energy as is well known.

Computer algebra shows that Eqs. (12) to (17) give:

$$\ddot{r} - r\dot{\phi}^2 = \frac{dm(r)}{dr}\left(c^2 m(r) + \frac{MG}{2\gamma^3 r\, m(r)^{1/2}} - \frac{3c^2}{2\gamma^2}\right) - \frac{1}{m(r)}\frac{dm(r)}{dr}\dot{\phi}^2 r^2\left(2 - \frac{MG}{2\gamma c^2 m(r)^{1/2}}\right) - MG\left(\frac{m(r)^{1/2}}{\gamma^3 r^2} + \frac{\dot{\phi}^2}{\gamma c^2 m(r)^{1/2}}\right) \quad -(18)$$

and:

$$r\ddot{\phi} + 2\dot{\phi}\dot{r} = r\dot{\phi}\dot{r}\left(\frac{1}{m(r)}\frac{dm(r)}{dr}\left(2 - \frac{MG}{2\gamma c^2 r\, m(r)^{1/2}}\right) + \frac{MG}{\gamma c^2 r^2 m(r)^{1/2}}\right) \quad -(19)$$

The S2 orbit is found by integrating Eqs. (18) and (19) numerically. The Newtonian limit of Eqs. (18) and (19) is described by:

$$\ddot{r} - r\dot{\phi}^2 = -\frac{MG}{r^2}, \quad -(20)$$

and

$$r\ddot{\phi} + 2\dot{\phi}\dot{r} = 0, \quad -(21)$$

and gives an elliptical orbit. Eqs. (18) and (19) give a variety of orbits as described in the immediately preceding UFT papers on www.aias.us and www.upitec.org.

The above argument shows that EGR is obsolete and that it must be replaced by m theory in physics and astronomy.

As shown in Note 419(2) the Newtonian theory of light deflection by gravitation produces:

$$\Delta\phi = \frac{2}{\epsilon} = \frac{2MG}{R_0 v_N^2} \quad -(22)$$

where R_0 is the distance of closest approach of an object of mass m orbiting an object of mass M and v_N is the Newtonian orbital velocity at closest approach. However the experimental deflection of light or electromagnetic radiation grazing a mass M is:

$$\Delta\phi = \frac{4MG}{R_0 c^2}. \quad -(23)$$

The experimental result is claimed to be very precise, and to be the result of contemporary precision astronomy. The experimental result is obtained straightforwardly as in Note 419(2) by using

$$m(r) = 1 \quad -(24)$$

so that:

$$\gamma = \left(1 - \frac{v_N^2}{c^2}\right)^{-1/2} \quad -(25)$$

The observed relativistic velocity v is defined by:

$$v = \gamma v_N \quad -(26)$$

where v_N is the Newtonian velocity. It follows that:

$$v_N^2 = \frac{v^2}{1 + \frac{v^2}{c^2}} \quad -(27)$$

and that:

$$\Delta\phi = \frac{2mG}{R_0 \left(\frac{v^2}{1 + \frac{v^2}{c^2}} \right)} \quad -(28)$$

so as v approaches c:

$$\Delta\phi \xrightarrow[v \to c]{} \frac{4mG}{R_0 c^2}. \quad -(29)$$

This is exactly the experimental result, obtained with a constant m (r) of one.

Einstein's elaborate method of obtaining Eq. (23) was shown in UFT150 to UFT155 to be obscure and erroneous due to neglect of torsion.

As shown in immediately preceding papers, the Newtonian orbital velocity (1) is modified under well defined approximations in m theory to:

$$v_N^2 = m(r)^{3/2} M G \left(\frac{2m(r)^{1/2}}{r} - \frac{1}{a} \right) \quad -(30)$$

Assuming that at closest approach:

$$\frac{1}{a} = \frac{1 - \epsilon}{R_0} \quad -(31)$$

The deflection of light in m theory becomes

$$\Delta\phi = m(r)^{3/2}\left(\frac{2MG}{R_0 v_N^2}\right) \quad -(32)$$

under the given approximations. In m theory:

$$v_N^2 = \frac{v^2}{\gamma^2} = v^2 m(r)\left(1 - \frac{v_N^2}{m(r)^2 c^2}\right) \quad -(33)$$

and it follows as in Note 419(2) that:

$$\Delta\phi \xrightarrow[v \to c]{} \left(\frac{1+m(r)}{m(r)^{1/2}}\right)\left(\frac{2MG}{R_0 c^2}\right) \quad -(34)$$

Any deviations from the experimentally claimed result (23) can be explained with m theory. These deviations may become apparent in the future with increasingly precise astronomy.

As shown in Note 419(4) the three laws of Kepler are modified by m theory, as is the whole of physics and astronomy.

Kepler's first law asserts that an orbit is an ellipse. This is changed completely in m theory, where the orbit is described by Eqs. (12) and (13). Kepler's second law of 1609 is that the areal velocity dA / dt of an orbit is constant:

$$\frac{dA}{dt} = \frac{L}{2m} = \text{constant}. \quad -(35)$$

In m theory Kepler's second law becomes:

$$\frac{dA}{dt} = \frac{1}{2}\frac{m(r)}{\gamma}\frac{L}{m} \quad -(36)$$

where L is the constant angular momentum (15) and γ the generalized Lorentz factor (16). Kepler's third law is an integration of the second law over one complete orbit.

Writing the second law as:

$$dt = \frac{2m}{L} dA \quad -(37)$$

integrate both sides as follows:

$$T = \int_0^t dt = \frac{2m}{L} \int_0^A dA \quad -(38)$$

to give:

$$T = \frac{2m}{L} A . \quad -(39)$$

The time T taken for one complete orbit is proportional to the area of the orbit A. For the Newtonian ellipse Kepler's third law can be expressed as:

$$T^2 = \frac{4\pi^2}{MG} a^3 . \quad -(40)$$

So any self consistent data set from astronomy for a Newtonian orbit must obey both Eqs. (1) and (40). In Section 3 it is shown that the Wikipedia data set does not do so and is self inconsistent. This is typical of Wikipedia, much of which is obsolete.

In m theory Kepler's third law becomes:

$$T = \frac{2m}{L} \int_0^A \frac{\gamma}{n(r)} dA \quad -(41)$$

and may deviate considerably from the original third law of Kepler. Eq. (41) is developed in Note 419(4).

As shown in detail in Note 419(5), the orbital linear velocity of m theory is:

$$v^2 = \frac{L^2 m(r)}{\gamma^2 m^2} \left(\frac{1}{r^2} + \frac{1}{r^4} \left(\frac{dr}{d\phi} \right)^2 \right) \quad -(42)$$

in plane polar coordinates (r , ϕ). In a whirlpool galaxy the spiral arms can be modelled in a simple way by:

$$\frac{1}{r} = \frac{\phi}{r_0} \quad -(43)$$

so:

$$v^2 \xrightarrow[r \to \infty]{} \frac{L^2 m(r)}{\gamma^2 m^2 r_0^2} . \quad -(44)$$

As shown in Note 419(5) this is constant if

$$m(r)^2 = A\left(1 + \frac{L^2}{m^2 r_0^2 c^2}\right) \quad -(45)$$

whee A is a constant.

In general:

$$v^2 = \frac{L^2 m(r)}{\gamma^2 m^2}\left(\frac{1}{r^2} + \frac{1}{r^4}\left(\frac{dr}{d\phi}\right)^2\right) \quad -(46)$$

where:

$$\frac{1}{\gamma^2} = m(r) - \frac{v^2}{m(r) c^2} \quad -(47)$$

so v can be found in terms of any m (r) and any $dr / d\phi$. For example if it is assumed that:

$$\frac{1}{r} = \frac{\phi}{r_0} \quad -(48)$$

it follows in m theory that if v is a constant at infinite r, as observed, then:

$$m(r)^2 \xrightarrow[r \to \infty]{} \text{constant}. \quad -(49)$$

From Eq. (46) using:

$$\frac{1}{r^2} \xrightarrow[r \to \infty]{} 0 \quad -(50)$$

it follows that: $$v^2 \xrightarrow[r\to\infty]{} \frac{L^2 n(r)}{\gamma^2 m^2 r^4}\left(\frac{dr}{d\phi}\right)^2. \quad -(51)$$

Using the experimentally observed result:

$$v^2 \xrightarrow[r\to\infty]{} \text{constant} := A \quad -(52)$$

the orbit must be:

$$\left(\frac{dr}{d\phi}\right)^2 = \frac{m^2 r^4 A}{n(r) L}\left(n(r) - \frac{v^2}{n(r)c^2}\right)^{-1}. \quad -(53)$$

This is the most general type of orbit that gives a constant v at infinite r. It determines the shape of any whirlpool galaxy.

In the approximation:

$$v \ll c \quad -(54)$$

it follows that:

$$\gamma^2 \sim \frac{1}{n(r)} \quad -(55)$$

so :

$$\frac{d\phi}{dr} = \frac{L n(r)}{m r^2 A^{1/2}} \quad -(56)$$

and:

$$\phi = \frac{L}{m A^{1/2}} \int \frac{n(r)}{r^2}\, dr. \quad -(57)$$

In the limit:

$$m(r) \rightarrow 1 \quad -(58)$$

this gives the spiral:

$$\phi = -\frac{L}{mA^{1/2}}\frac{1}{r}. \quad -(59)$$

More generally:

$$\left(\frac{dr}{d\phi}\right)^2 = \frac{m^2 r^4 A}{m(r)}\left(m(r) - \frac{v^2}{m(r)c^2}\right)^{-1} \quad -(60)$$

which has been derived in the limit:

$$v^2 \longrightarrow A = \text{constant} \quad -(61).$$

so:

$$\left(\frac{dr}{d\phi}\right)^2 = \frac{m^2 r^4 A}{m(r)}\left(m(r) - \frac{A}{m(r)c^2}\right)^{-1} \quad -(62)$$

and the orbit is:

$$\phi = \frac{1}{m}\int\left(\frac{m(r)}{Ar^4}\left(m(r) - \frac{A}{m(r)c^2}\right)\right)^{1/2} dr \quad -(63)$$

This equation gives different galactic structures defined by a choice of m (r). So in m theory galaxies are maps of spherical spacetime.

3. ANALYSIS OF SELF CONSISTENCY, COMPUTATIONS AN D GRAPHICS.

Section by Horst Eckardt.

Development of m theory part two: The orbit of S2, light deflection due to gravitation and velocity curve of a whirlpool galaxy

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3 Analysis of self consistency, computations and graphics

3.1 S2: variation of central mass

The relativistic equations of motion for plane polar coordinates (r, ϕ) in m theory are given by Eqs.(18, 19) and were discussed in UFT 416. For the numerical solution we used the experimental initial conditions given at the beginning of section 2 where $r = r_{\min}$ is the radius of closest approach of the S2 star to the centre of the galaxy and $v = v_{\min}$ is the corresponding velocity. The relevant experimental data are presented in the first data line of Table 1. A precession angle of the elliptic orbit was not measured so far and seems to be quite small.

Using the experimental initial values in the calculation leads to the results shown in the second line of Table 1. There are quite large deviations in the orbit period T and the maximum radius. Test runs showed that the results depend sensitively on the value of the central mass M. This is not very precisely known. Therefore we varied this value in a series of calculations, all with m(r)=1. The variations found for T, ϵ, $r_{\max}$ and $\Delta\phi$ are graphed in Figs. 1-4.

Concerning T, the experimental value of T was plotted as a triangle at the place of the experimental M value (Fig. 1). T has significantly to be shifted to a lower M to achieve agreement with the curve. In other words, the data set is not Keplerian or Newtonian. The eccentricity (Fig. 2) decreases linearly with M, quite astonishing. It has to be shifted to nearly the same value of M as is the case for T. This might give a hint that this value is the true central mass, as far as this model with constant spacetime curvature is used.

The maximum radius (Fig. 3) behaves qualitatively very similar to the orbit period. It can be seen that the point of the experimental value has also to be shifted to a lower M value to coincide with the curve, but to a bit higher value

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	T [y]	ϵ	$r_{\max}$ [10^{14} m]	$\Delta\phi$ [rad]
experiment	16.05	0.88466	2.73464	?
exp. initial conditions	9.65	0.83724	2.02688	6.0636e-4
best fit for M	16.07	0.88323	2.89596	5.7702e-4
exp. data with m=0.9877	16.07	0.88332	2.89596	5.9144e-4

Table 1: Parameters of S2 star orbit (recent experimental data and calculations).

than for T and ϵ. This shows that some consistency problems of experimental or theoretical data remain. The precession angle (Fig. 4) grows linearly with M, similarly as ϵ decreases with M. There is no experimental value known for precession.

The central mass (in Newtonian approximation) can be computed according to Eq.(40) by

$$M_N = \frac{4\pi^2 a^3}{T^2 G} \tag{64}$$

where a is the semi major axis of the elliptic orbit. Inserting experimental values gives exactly $M_N = 8.572 \cdot 10^{36}$ kg, which means that the mass value has been derived by the astronomers from Newtonian theory. Therefore we can be quite sure that the discrepancy between calculated and experimental data is from this assumption. To obtain the right orbit period, we have to use an effective mass which is $M_{\text{eff}} = 8.3627 \cdot 10^{36}$ kg. According to note 419(4), we have the proportionality

$$T \propto \frac{\gamma}{\mathrm{m}(r)}. \tag{65}$$

As the calculations have shown, the γ factor is 1.0003 in maximum, i.e. it plays no role in the above equation and the average m function must be

$$\overline{m} = \sqrt{\frac{M_{\text{eff}}}{M_N}} = \sqrt{\frac{8.3627}{8.572}} = 0.9877. \tag{66}$$

Using this constant value for $\mathrm{m}(r)$ and the experimental mass M gives the results in the fourth line of Table 1. Obviously a constant $\mathrm{m}(r)$ has practically the same effect as changing the central mass value.

The elliptic orbit of the S2 star, obtained by the "best fit" calculation, is graphed in Fig. 5, demonstrating the high ellipticity of the orbit. The other trajectories are graphed in Figs. 6-8. All curves are presented in SI units. Angular momentum and total energy only deviate from the Newtonian values in the regions where the mass is near to the centre. The γ factor only deviates from unity in this periastron region.

3.2 S2: consistency of experimental data

Using the Keplerian formula (40) and experimental a and M, the result for the orbit period is

$$T = 14.55\,\text{years}, \tag{67}$$

compared to the experimental $T = 16.05$ years. There are 9% in difference. Using the Newtonian velocity

$$v^2 = MG\left(\frac{2}{r} - \frac{1}{a}\right) \tag{68}$$

(with experimental v) and resolving for M gives

$$T = 14.71\,\text{years} \tag{69}$$

which is not much different. The discrepancy to the experimentally measured value remains, indicating that the S2 orbit is not Newtonian, albeit having the shape of an ellipse.

Another point of discrepancy is the semi major axis a. Using the values of a and ϵ given at the beginning of section 2, we obtain for the minimum radius of an ellipse:

$$r_{\text{min}} = a(1-\epsilon) = 1.6736 \cdot 10^{13}\ \text{m}. \tag{70}$$

This is different from the value $1.7952 \cdot 10^{13}$ m measured in Mai 2018 at the point of closest approach. Probably the value of a has to be corrected when the point of maximum distance is measurable in 2026.

The ratio of v/c at $r = r_{\text{min}}$ is 2.55%, therefore relativistic effects of special relativity are small. The formula (4) of m theory was resolved for m(r) in UFT 417, section 3 (quartic equation) and gives for the experimental velocity v_{min}:

$$m(r_{\text{min}}) = 0.9895. \tag{71}$$

For comparison, the value from the Newtonian velocity, Eq.(1), gives $m(r_{\text{min}}) = 0.999999$ as as expected. The results are consistent with the fact that the ratio v/v_N is 98.9%, however we do not know the experimental error. If further points of velocity measurement were available, we would obtain more or less m=1 because the radius is much larger off the periastron.

The orbit precession in the computations (Table 1) is only about +0.0033 degrees per orbit (forward precession). This differs vastly from the value of Einstein theory which gives 0.2180 degrees, a discrepancy by a factor of hundred.

3.3 S2: Special calculations with m(r)

We did several test calculations with a non-constant m function. Using the Einsteinian function m(r)=$1-r_0/r$ with the so-called Schwarzschild radius $r_0 = 2MG/c^2$ gives disastrous results, the orbit period shrinks by a factor of about 10. Reducing the term r_0/r by a factor of 100:

$$\text{m}(r) = 1 - \frac{0.01\, r_0}{r} \tag{72}$$

still gives half the orbit period only, although the correction to unity is extremely small. The sign of the correction has to be changed to arrive at the experimental $T = 16.05$ years. Using the extended version

$$\text{m}(r) = 1 - \frac{0.01\, r_0}{r} - \frac{\alpha}{r^2} \tag{73}$$

with $\alpha > 0$ worsens the result as expected. With $\alpha = -2.25 \cdot 10^{23}\,\mathrm{m}^2$ the experimental orbit period can roughly be reproduced, but there is a huge precession of about $1/3 \cdot 2\pi$.

Obviously it is very difficult to find appropriate parameters so that a variable $\mathrm{m}(r)$ produces a curve similar to the experimentally found ellipse. The orbit is extraordinarily sensitive to the derivative terms of $\mathrm{m}(r)$. The mathematical system is not well conditioned, it behaves like in chaos theory. One would need special numerical methods to do appropriate analysis. As an example we computed the dynamics for the m function shown in Fig. 9. This deviates from unity only in the range of 10^{-5}. The result is a strongly precessing orbit with -34 degrees (backward precession), see Fig. 10. With a constant $\mathrm{m}(r)$, all these numerical problems disappear, the derivative terms of m(r) are responsible for the numerical sensitivity. The reason may be that they are partially weighted by a very large factor of c^2.

In Figs. 11-14 the curves of dynamics are shown and can be compared to the corresponding curves of the well behaved case (Figs. 5-8). The γ factor (Fig. 11) is slightly larger than in Fig. 6. The angular momentum deviates from the Newtonian value over the full orbital range, compared to Fig. 7. The most significant deviation can be seen by comparing Figs. 8 and 13. The total non-relativistic energy deviates extremely from the constant relativistic value, continuing even into the positive range. This means that such a state would be unbound in the Newtonian limit. For a non-constant $\mathrm{m}(r)$, there is a vacuum force (see Eq. (33) of UFT 417). This is graphed in Fig. 14. It increases hyperbolically when the star moves to the centre.

3.4 m function orbits of galaxies

According to Eq. (57), the angular function $\phi(r)$ of galaxies in m theory is for $v \ll c$

$$\phi = c_1 \int \frac{\mathrm{m}(r)}{r^2} dr \tag{74}$$

with a constant c_1. If m is constant ($\mathrm{m}=\mathrm{m}_1$), the hyperbolic spiral follows:

$$\phi_h = -\frac{c_1 m_1}{r}. \tag{75}$$

When m is not constant, more complicated, spiral-like structures follow. In the case of Schwarzschild function

$$\mathrm{m}(r) = 1 - \frac{r_0}{r} \tag{76}$$

The integral in (74) is solveable analytically:

$$\phi_S = \frac{c_1}{2r_0} \left(1 - \frac{r_0}{r}\right)^2. \tag{77}$$

This function has to be inverted so that the graph $r(\phi_S)$ can be produced. The two solutions are

$$r(\phi_S) = \frac{1}{2\, r_0\, \phi_S - c_1} \left(-c_1 r_0 \pm \sqrt{2\, r_0^2\, \phi_S}\right). \tag{78}$$

These two solutions are graphed in Fig. 15, together with the hyperbolic spiral (75). The degree of spiralling is less pronounced in the Schwarzschild-like spirals.

As an example that has to be handled numerically we used the exponential m function

$$\mathrm{m}(r) = 2 - \exp\left(\log\left(2\right)\,\exp\left(-\frac{r}{R}\right)\right). \tag{79}$$

Integral (74) was evaluated numerially for suitable constants c_1 and R. Since pairs of values (r, ϕ) are obtained, inversion of functional dependence is simple. The result is graphed in Fig. 16. It looks like an exponential (or logarithmic) spiral, similar as the shrinking orbits obtained from this m function (79) in UFT 417.

In total, the orbital parameters of the S2 star can be explained by the relativistic ECE equations of motion, either with an effective central mass or an m function of general relativity. Experimental data are too imprecise to draw a final conclusion. The m theory is able to explain a wide range of astronomical effects including structures of galaxies.

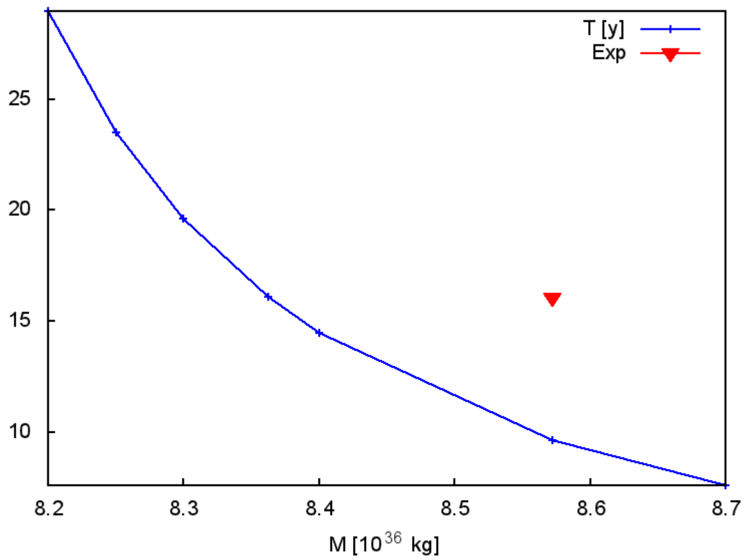

Figure 1: Dependence of orbit period on central mass.

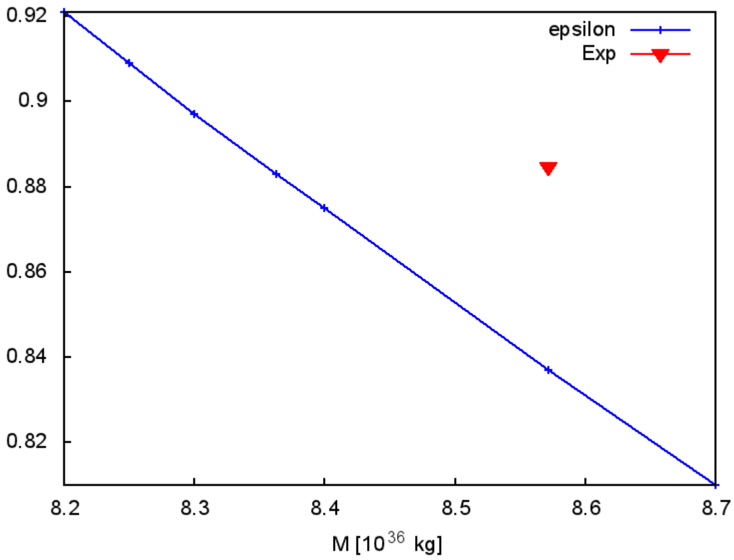

Figure 2: Dependence of eccentricity on central mass.

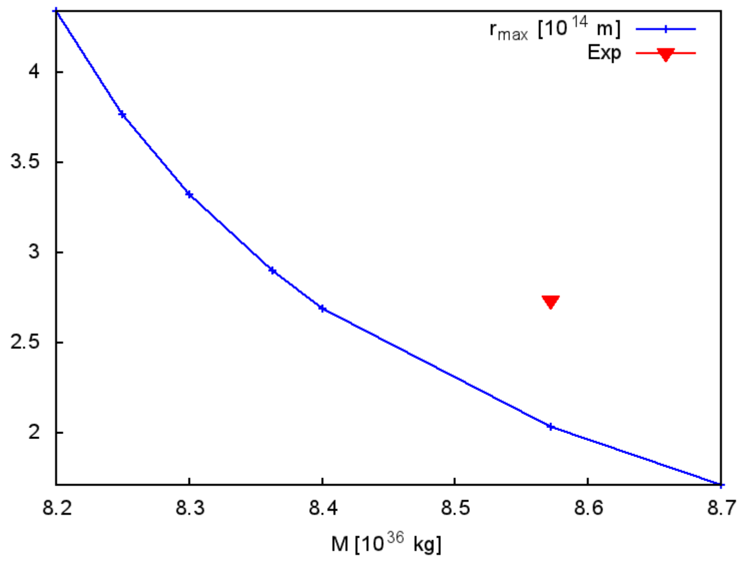

Figure 3: Dependence of maximum radius on central mass.

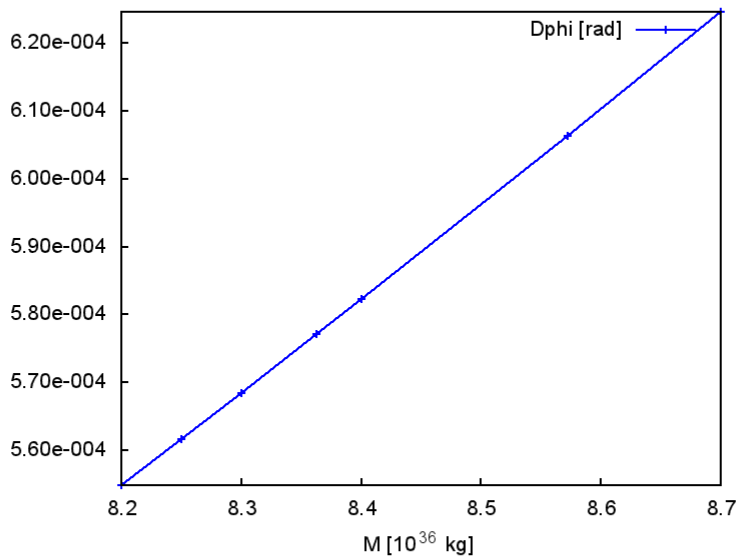

Figure 4: Dependence of precession angle on central mass.

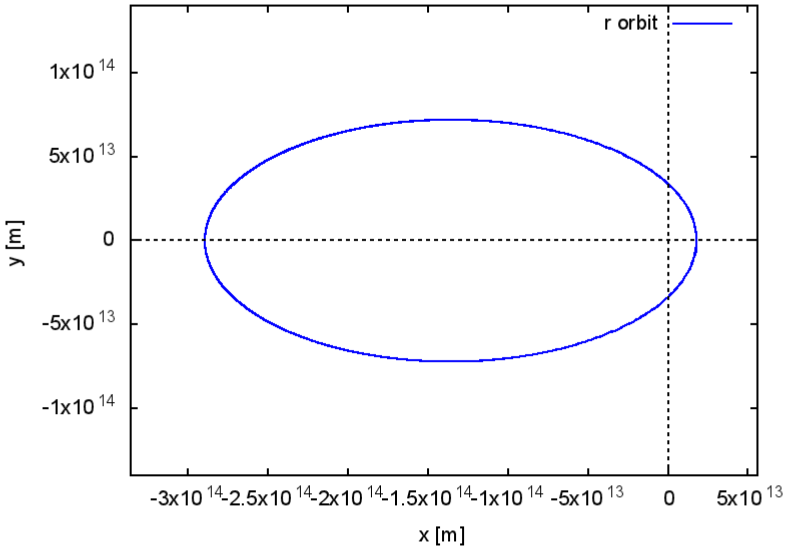

Figure 5: Orbit of S2 star, best fit.

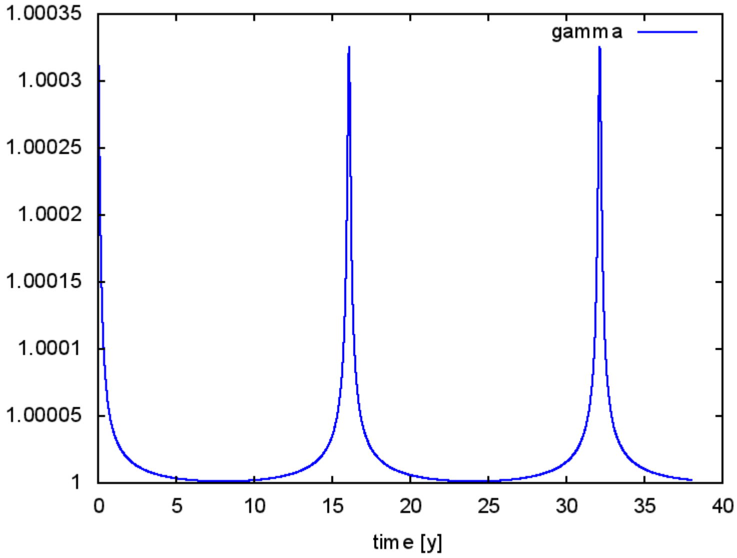

Figure 6: Relativistic γ factor of S2 star, best fit.

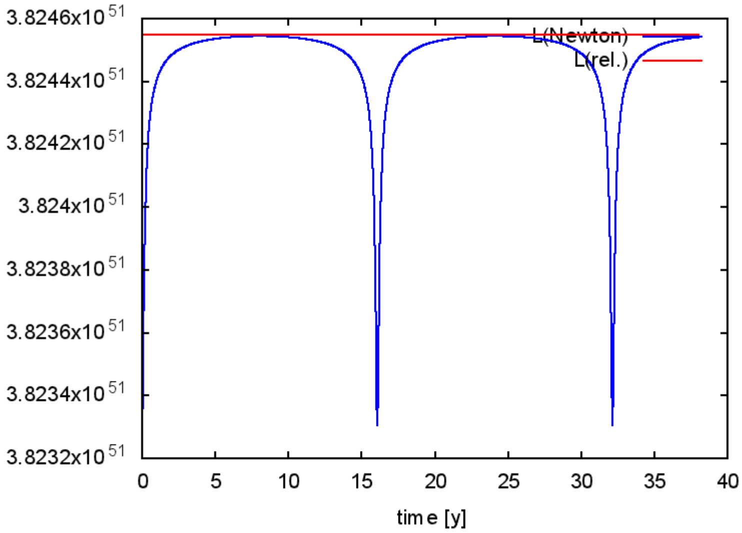

Figure 7: Relativistic and non-relativistic angular momentum of S2 star, best fit.

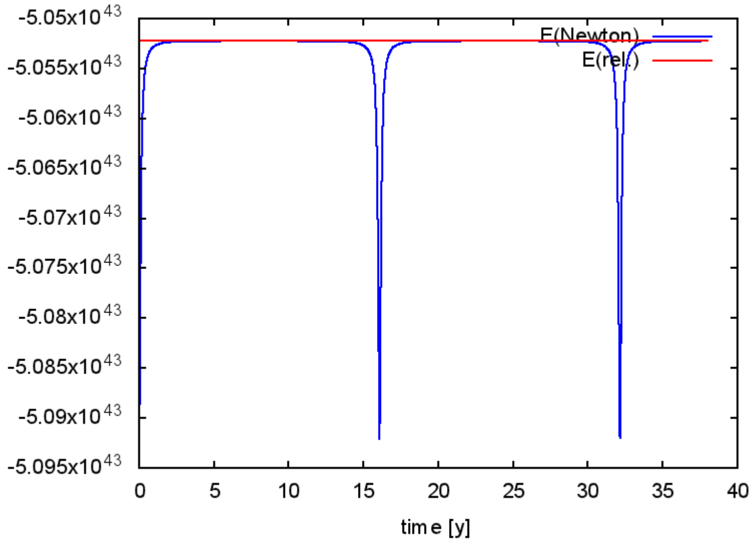

Figure 8: Relativistic and non-relativistic total energy of S2 star, best fit.

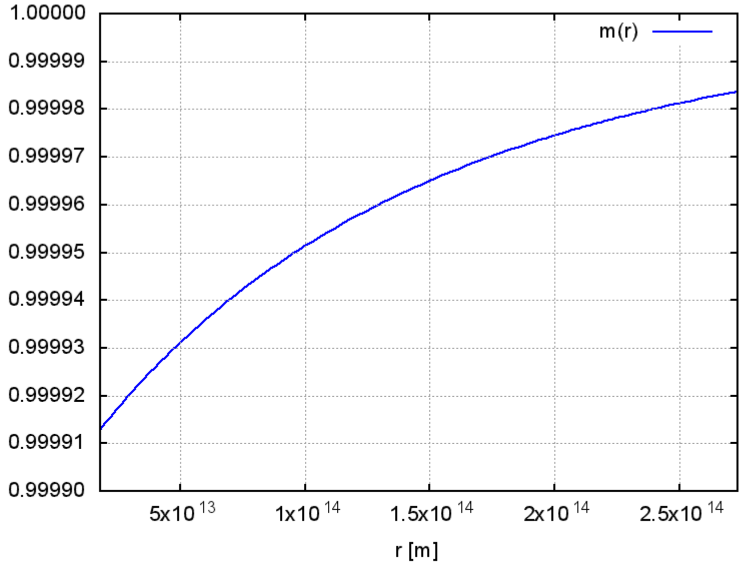

Figure 9: Model function m(r).

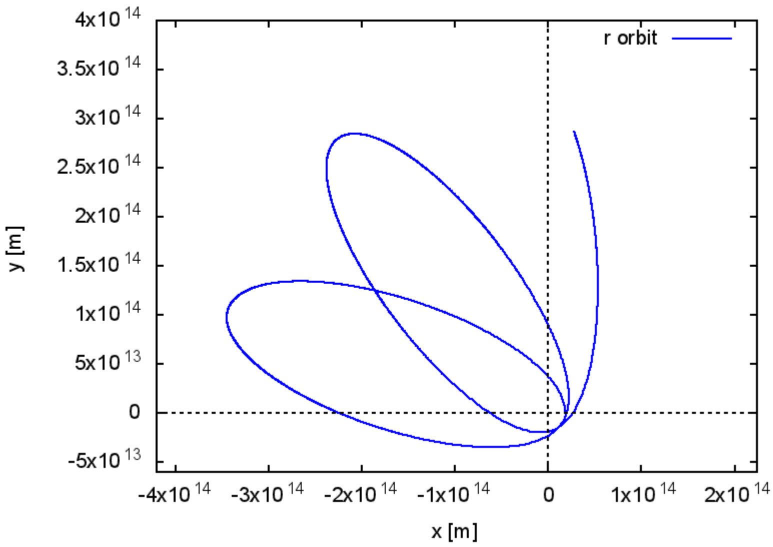

Figure 10: Orbit for selected m(r).

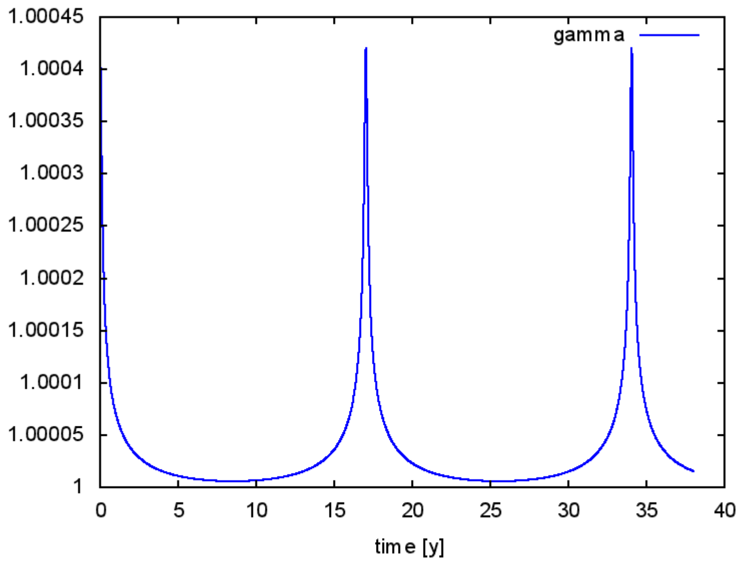

Figure 11: Relativistic γ factor for selected m(r).

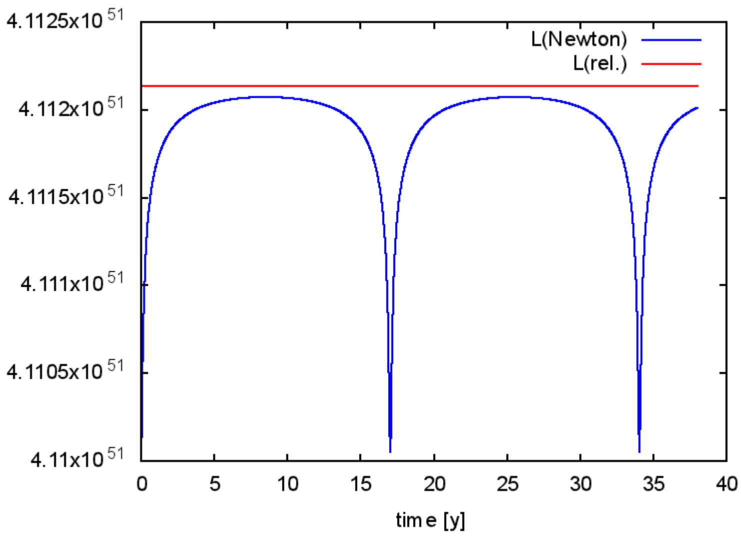

Figure 12: Relativistic and non-relativistic angular momentum for selected m(r).

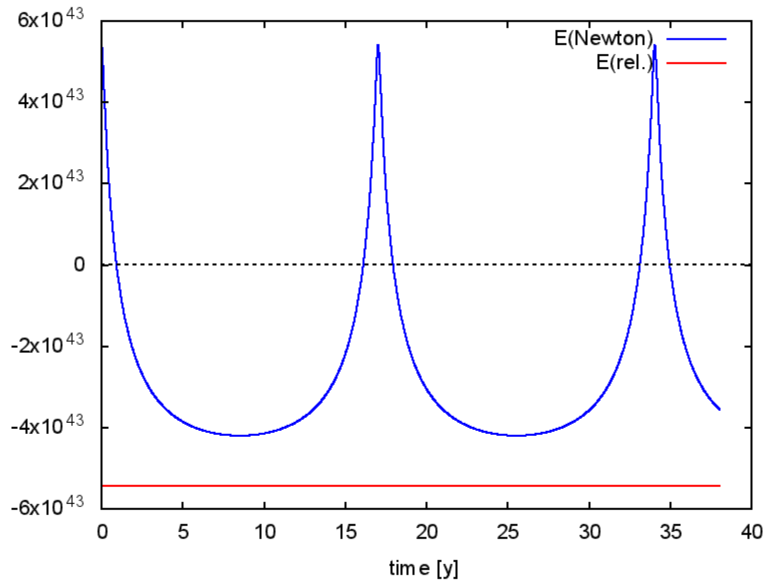

Figure 13: Relativistic and non-relativistic total energy for selected m(r).

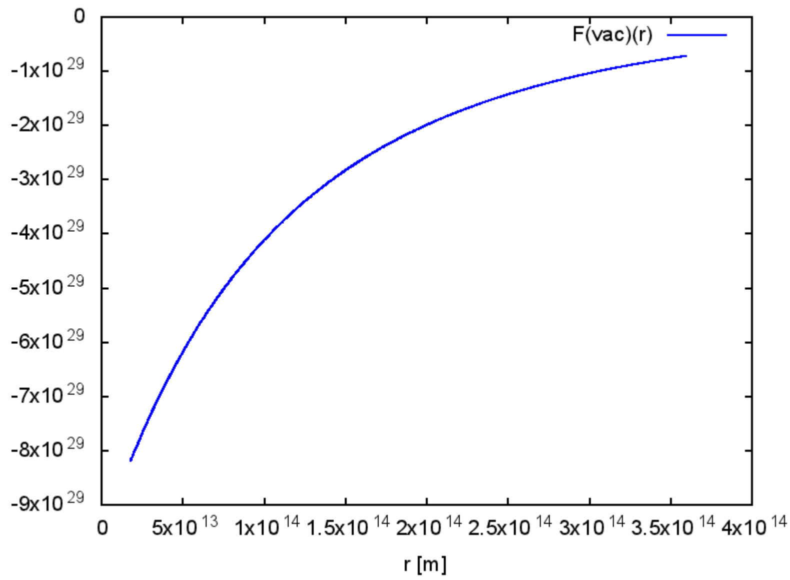

Figure 14: Vacuum force for selected m(r).

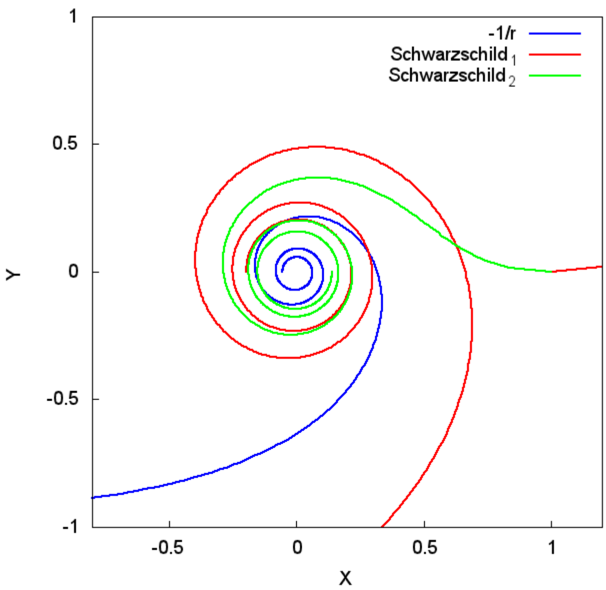

Figure 15: Spiral orbits of hyperbolic spiral and Schwarzschild spiral of Eq.(78).

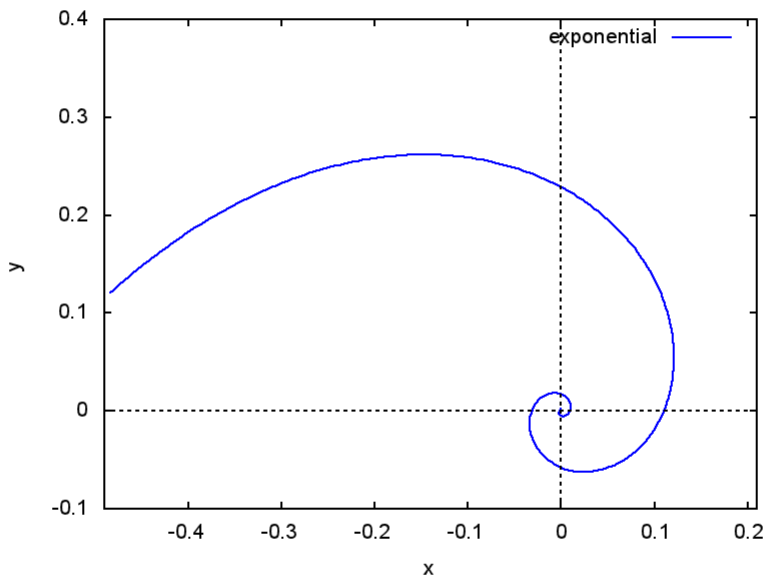

Figure 16: Spiral orbits of generalized exponential spiral of Eq.(79).

ACKNOWLEDGMENTS

The British Government is thanked for a Civil List Pension and the staff of AIAS and others for many interesting discussions. Dave Burleigh, CEO of Annexa Inc., is thanked for voluntary posting, site maintenance and feedback maintenance. Alex Hill is thanked for many translations, and Robert Cheshire and Michael Jackson for broadcasting and video preparation.

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